THE OXYGEN COST OF A MINE ESCAPE

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Background

- **Joint MSHA/NIOSH Project**
- **Involving 99 mines in six states**
- **700 miners**
- **Currently there are approximately 900 active underground coal mines in the United States employing approximately 50,000 miners**
- **Data was collected on the escape route as well as each participating miner**

Objectives

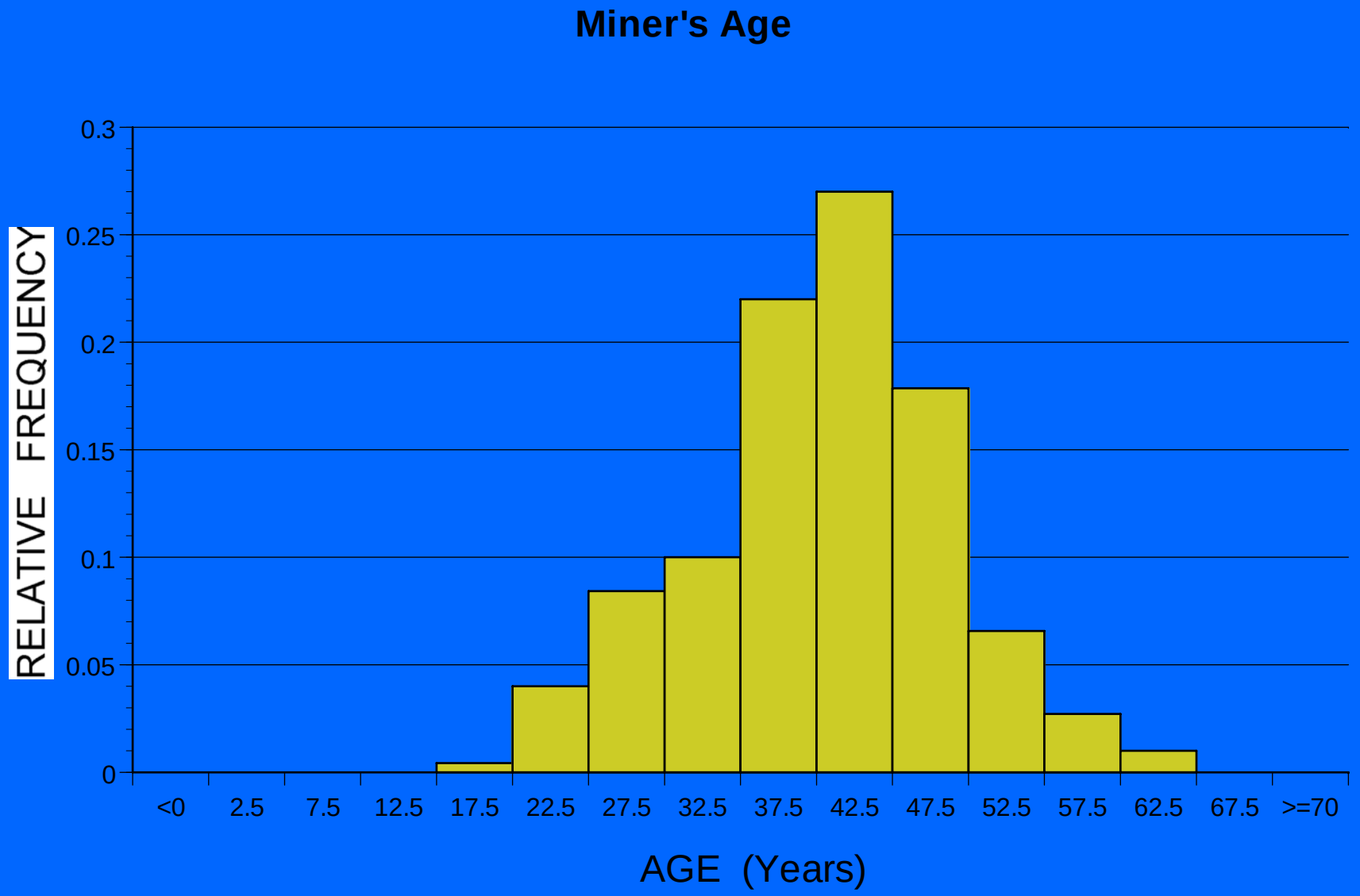
- **To gather in-mine data on escape times, distances and heart rates in order to predict how much oxygen is needed for a mine escape**
- **To compare oxygen consumption bare-faced versus using an SCSR**
- **To provide a scientific basis for practical escape planning involving all major factors**

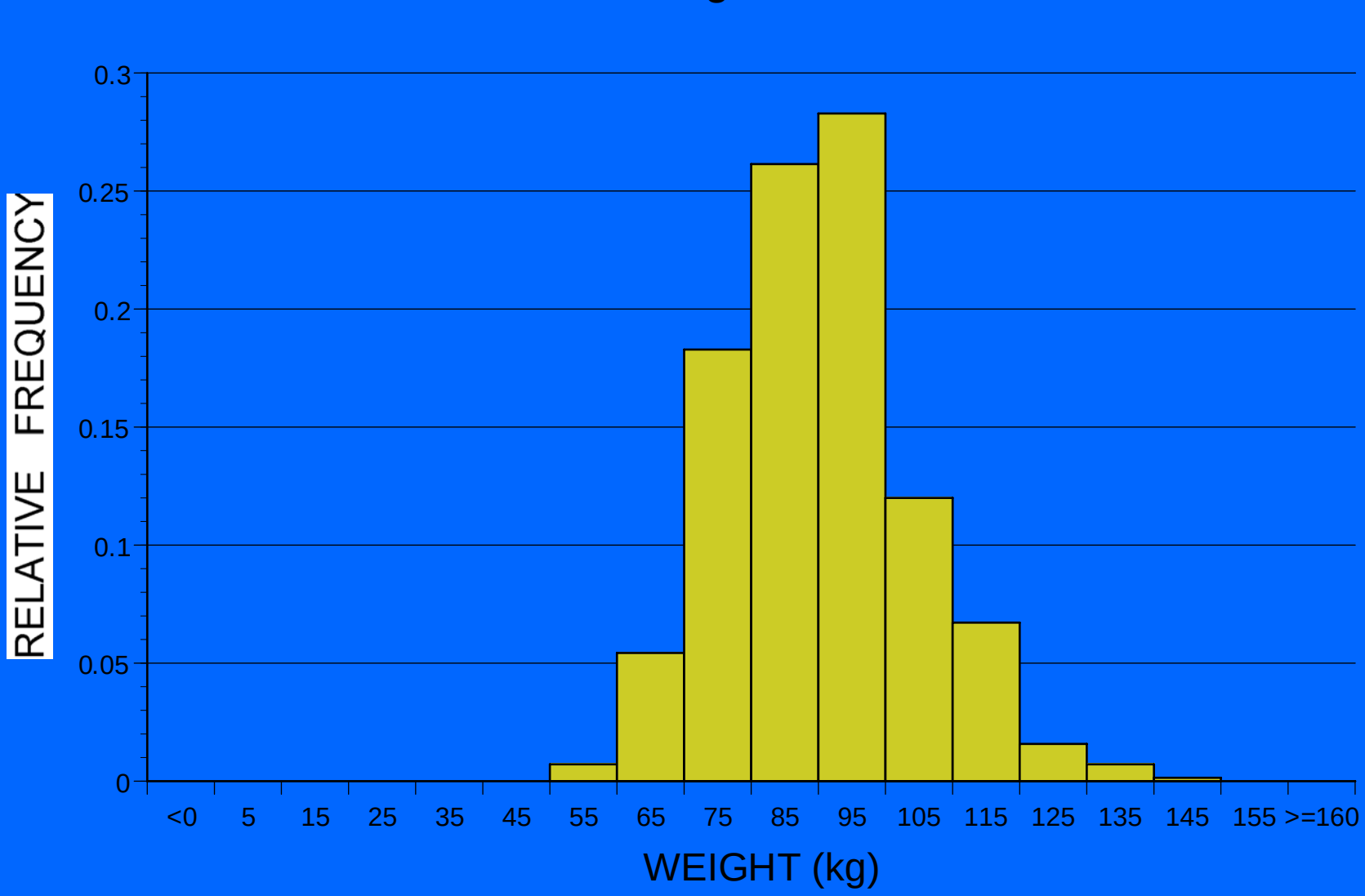
Protocol

- **Escape means taking a miner on foot and under oxygen from the deepest point of penetration in the mine to the surface**
- **Day 1- 5 miners make a mock escape barefaced while wearing a recording pulse-rate monitor**
- **Day 2 - At least one miner escapes using an SCSR**

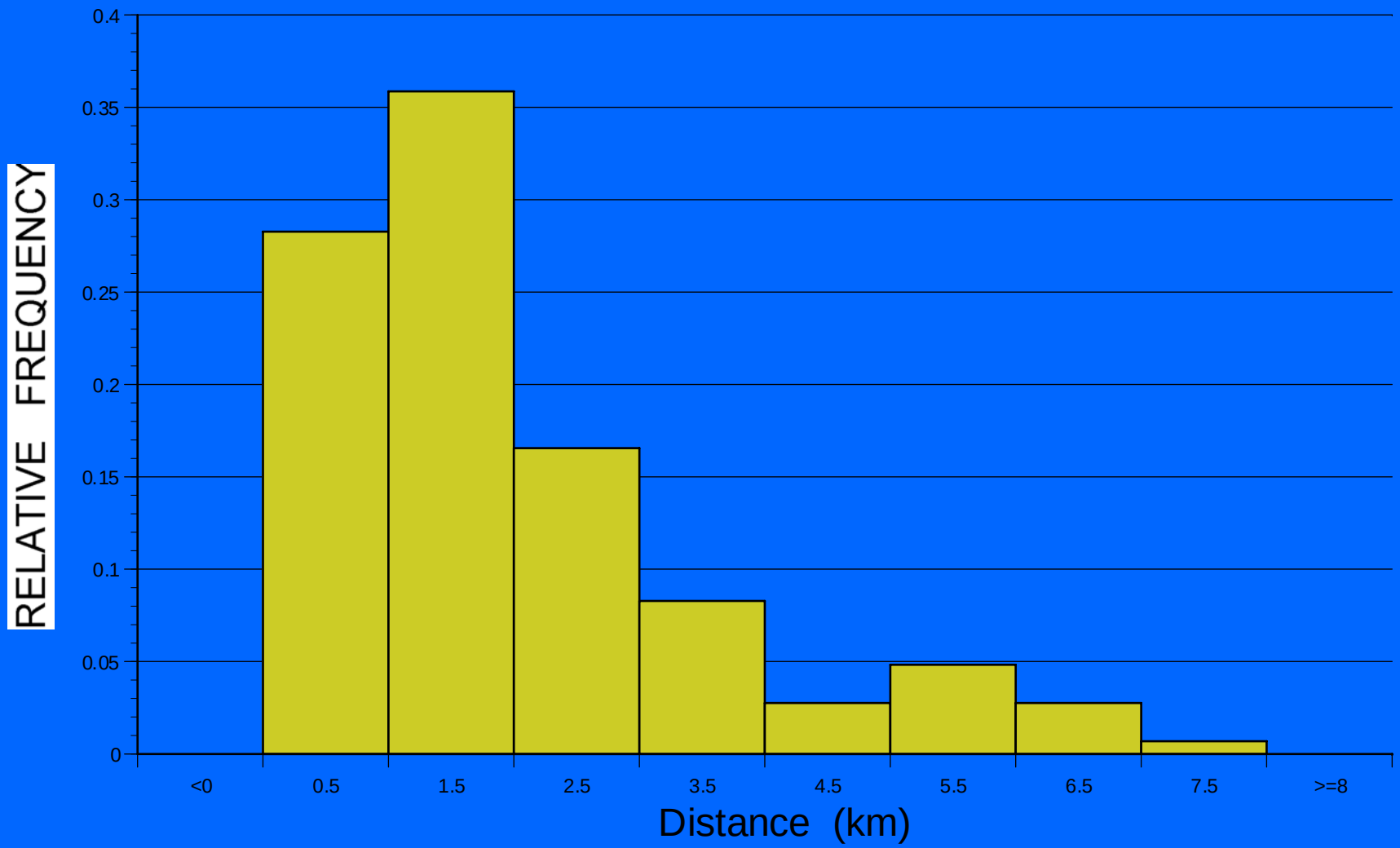
Analysis

- **Histograms**
  - **Age**
  - **Weight**
  - **Escape Distance**
  - **Escape Time**
  - **Speed**
  - **Oxygen Uptake**
  - **Oxygen Cost**
  - **Oxygen used**

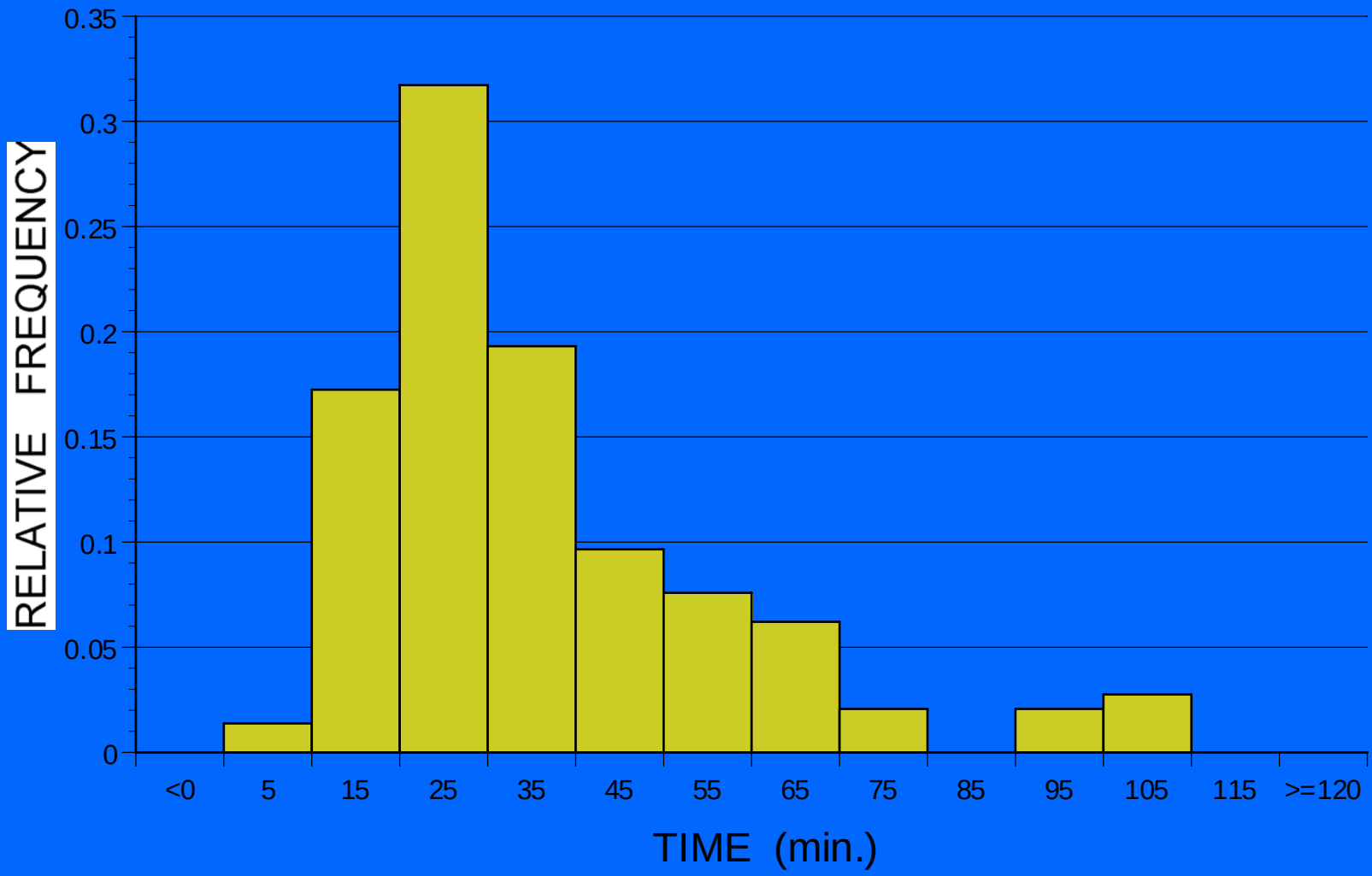

Miner's Age
RELATIVE FREQUENCY
0.3
0.25
0.2
0.15
0.1
0.05
0
<0
2.5
7.5
12.5
17.5
22.5
27.5
32.5
37.5
42.5
47.5
52.5
57.5
62.5
67.5
>=70
AGE (Years)


Miner's Weight
RELATIVE FREQUENCY
0.3
0.25
0.2
0.15
0.1
0.05
0
<0
5
15
25
35
45
55
65
75
85
95
105
115
125
135
145
155
>=160
WEIGHT (kg)

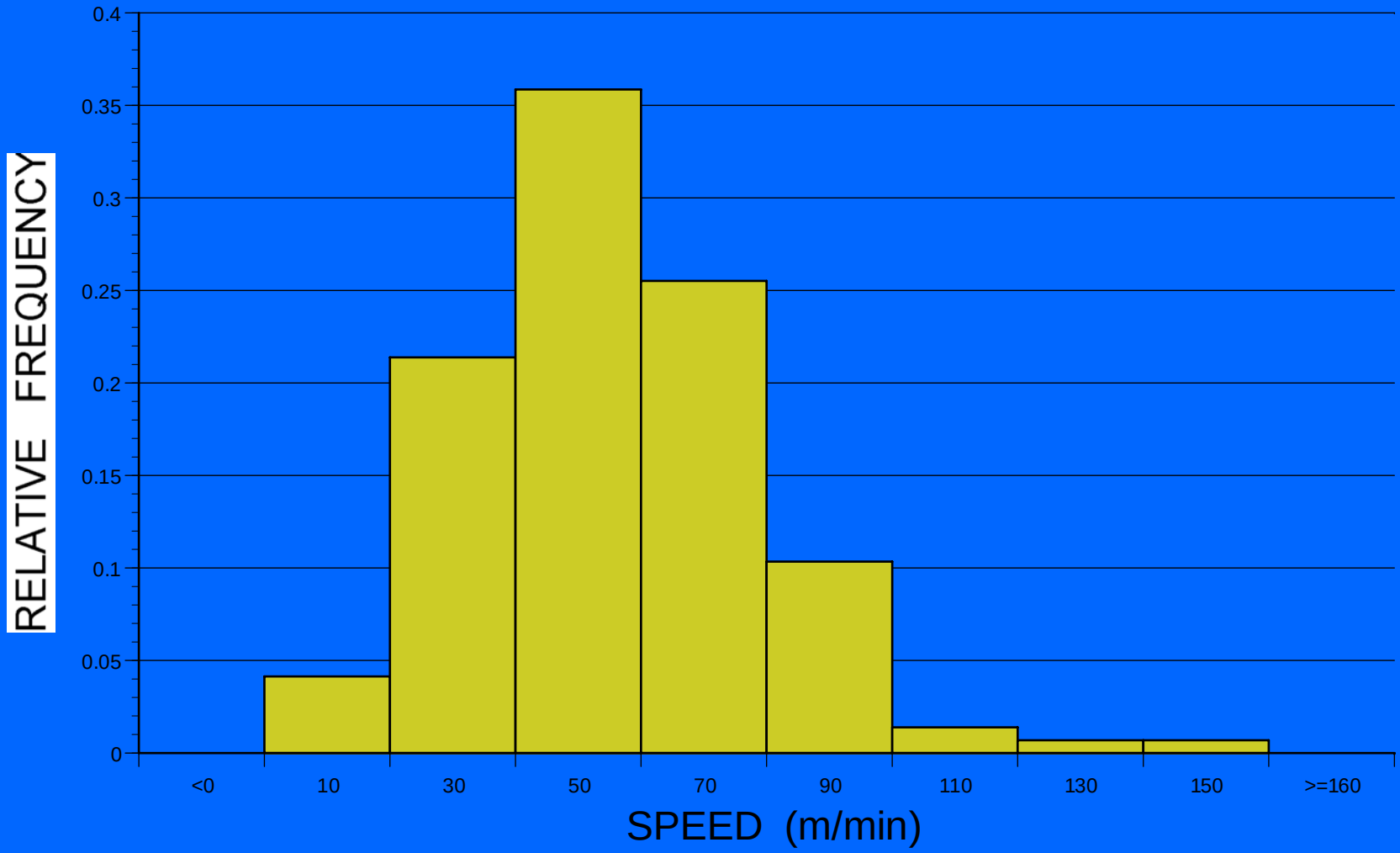
Escape Distance (All Mines)

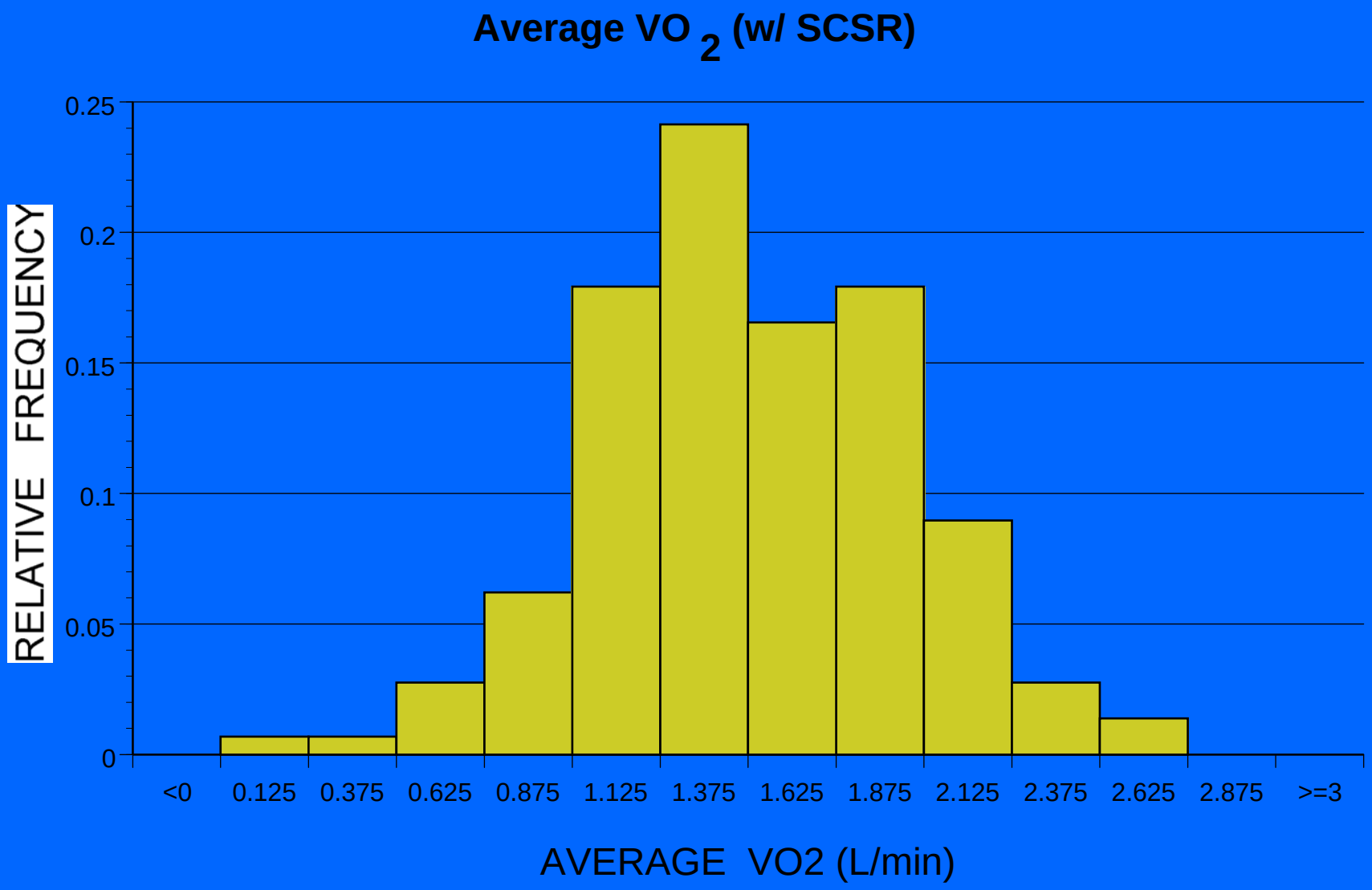


Escape Time (w/ SCSR)



Speed (w/ SCSR)


RELATIVE FREQUENCY
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
<0
10
30
50
70
90
110
130
150
>=160
SPEED (m/min)

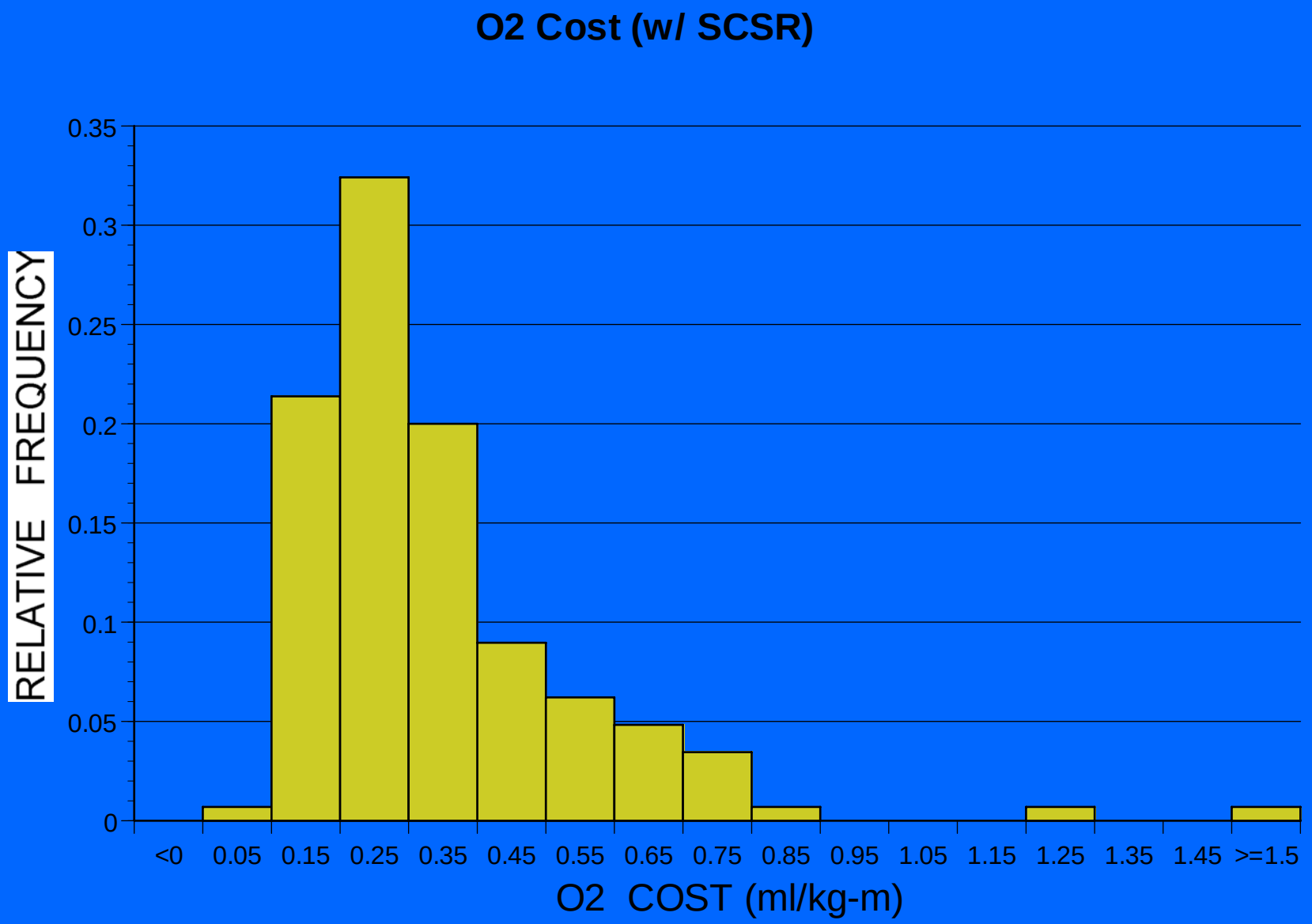

Average VO 2 (w/ SCSR)
RELATIVE FREQUENCY
0.25
0.2
0.15
0.1
0.05
0
<0
0.125
0.375
0.625
0.875
1.125
1.375
1.625
1.875
2.125
2.375
2.625
2.875
>=3
AVERAGE VO2 (L/min)

Oxygen Consumption Rate

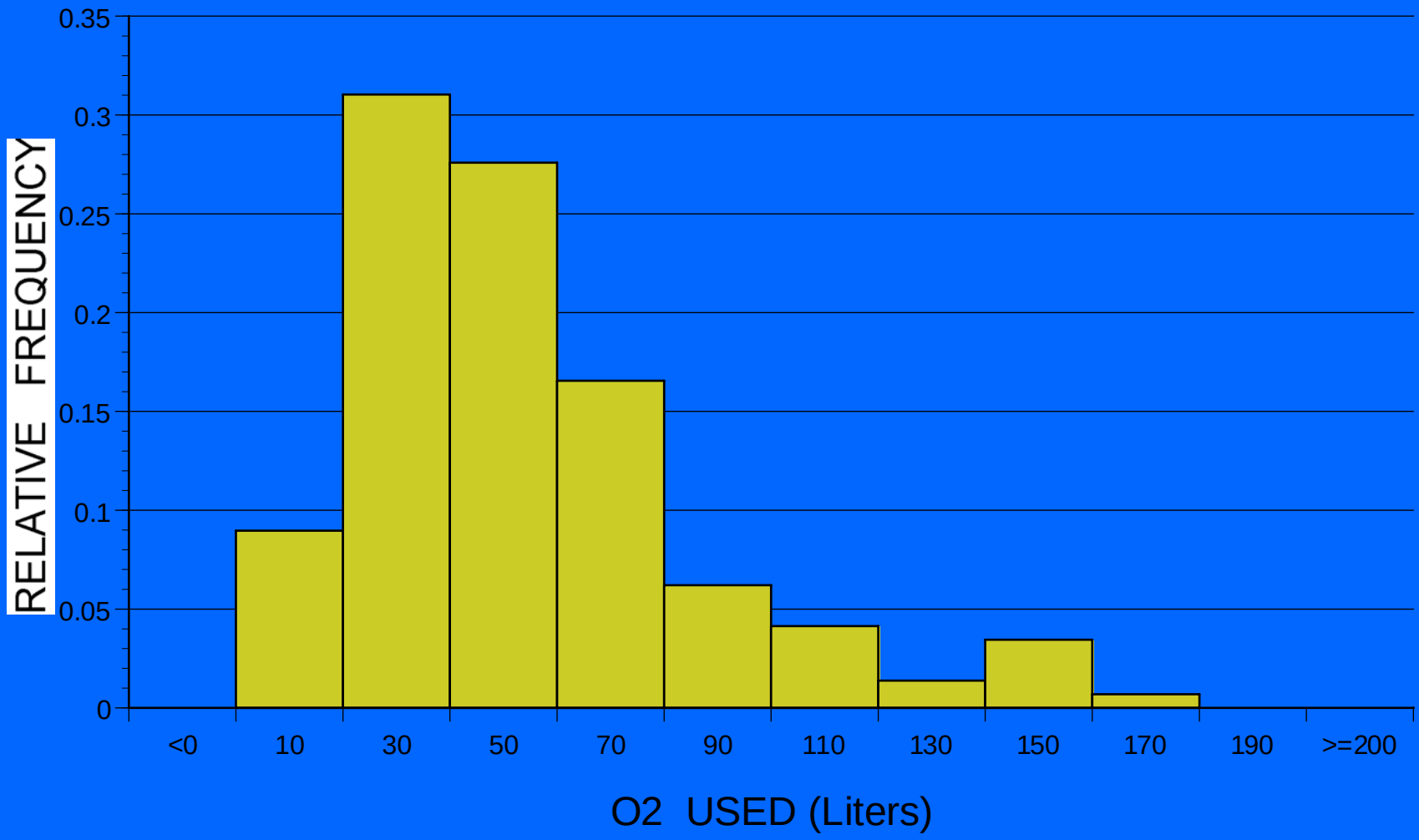
- **HR = Heart Rate (beats per minute)**
- **VO_2 = Rate of Oxygen consumption (liters of oxygen per minute)**
- **$HR = b + m * VO_2$**
- **$VO_2 = b_1 + m_1 * HR$**
  - **Straight line relationship**
  - **Intercepts (b & b_1) and slopes (m and m_1) are known**
  - **Oxygen consumed = Area under VO_2 vs. time curve**
  - **Oxygen consumed = Average VO_2 x Escape Time**

Relationships from Research

- HR = 36 VO_2 + 66 (Penn State, 1977)
- HR = 39 VO_2 + 68 (Bureau of Mines, 1981)
- HR = 37 VO_2 + 66 (Bureau of Mines, 1995)


O2 Cost (w/ SCSR)
RELATIVE FREQUENCY
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
<0
0.05
0.15
0.25
0.35
0.45
0.55
0.65
0.75
0.85
0.95
1.05
1.15
1.25
1.35
1.45
>=1.5
O2 COST (ml/kg-m)

O_2 Used (w/ SCSR)



Conclusions

- **The study demonstrated that it is possible to project, on a mine-by-mine basis:**
  - **The difficulty of the mine escape**
  - **The amount of oxygen that would be required for a mine escape knowing the body weight and heart rates of the escaping miners**
  - **This would provide a practical way of optimizing the mine escape plan so that there would be enough SCSRs for miners to make the mine escape**

Conclusions

- Escape speed - 15% slower while using an SCSR
- Travel time - 15% longer while wearing an SCSR
- Weight - a miner consumes oxygen in proportion to his/her weight
- A practical, scientific approach for planning